The DES Observing Plan

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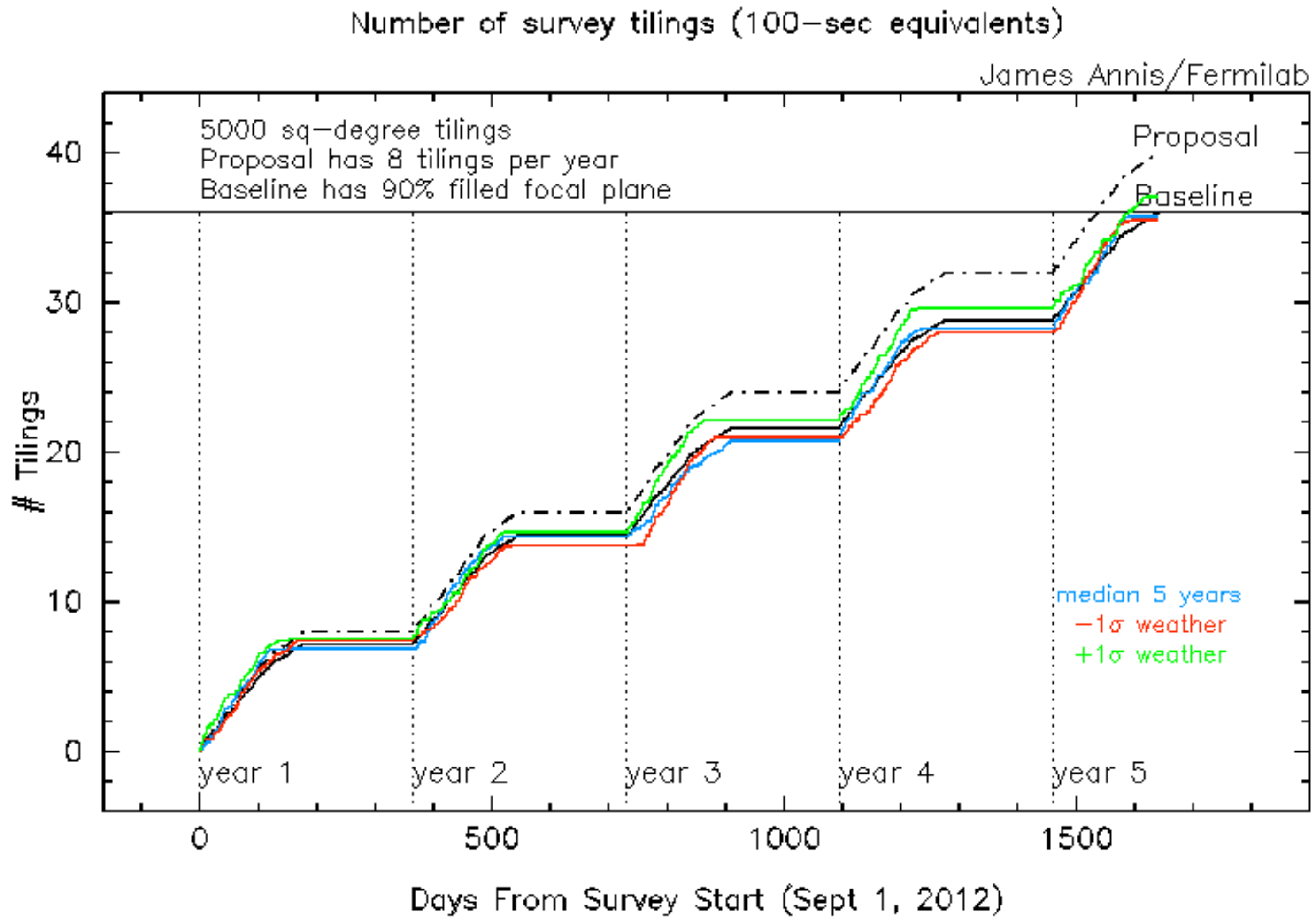
February 26, 2010

The Observing Plan

- Preliminary Observing Plan
    1. To be submitted to the DES Director, then to DES Council, then to CTIO Director
- Observing Plan
    1. To be submitted to the DES Director, then to the DES Council, then to the NOAO Survey Time Allocation Committee, once a year
- Content:
    1. Track survey progress
    2. Procedures for photometric and astrometric calibration
    3. Planned observation sequence
- Input: The Calibration Plan
    1. http://des-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=4160

DARK ENERGY SURVEY

Survey Completion: tilings



- We use the metric of equivalent tilings to judge survey progress
  - 36 100-second 5000 sq-degree tilings
  - sum image area in single tilings, ignoring overlaps
- Justification:
  - 5000 sq-degrees in single bandpass is a tiling
  - DECam fill factor of 90%: 90%*40 tiling equivalents= complete at 36 tilings
    - tiling equivalent: scale actual exposure to norm exposure

But,

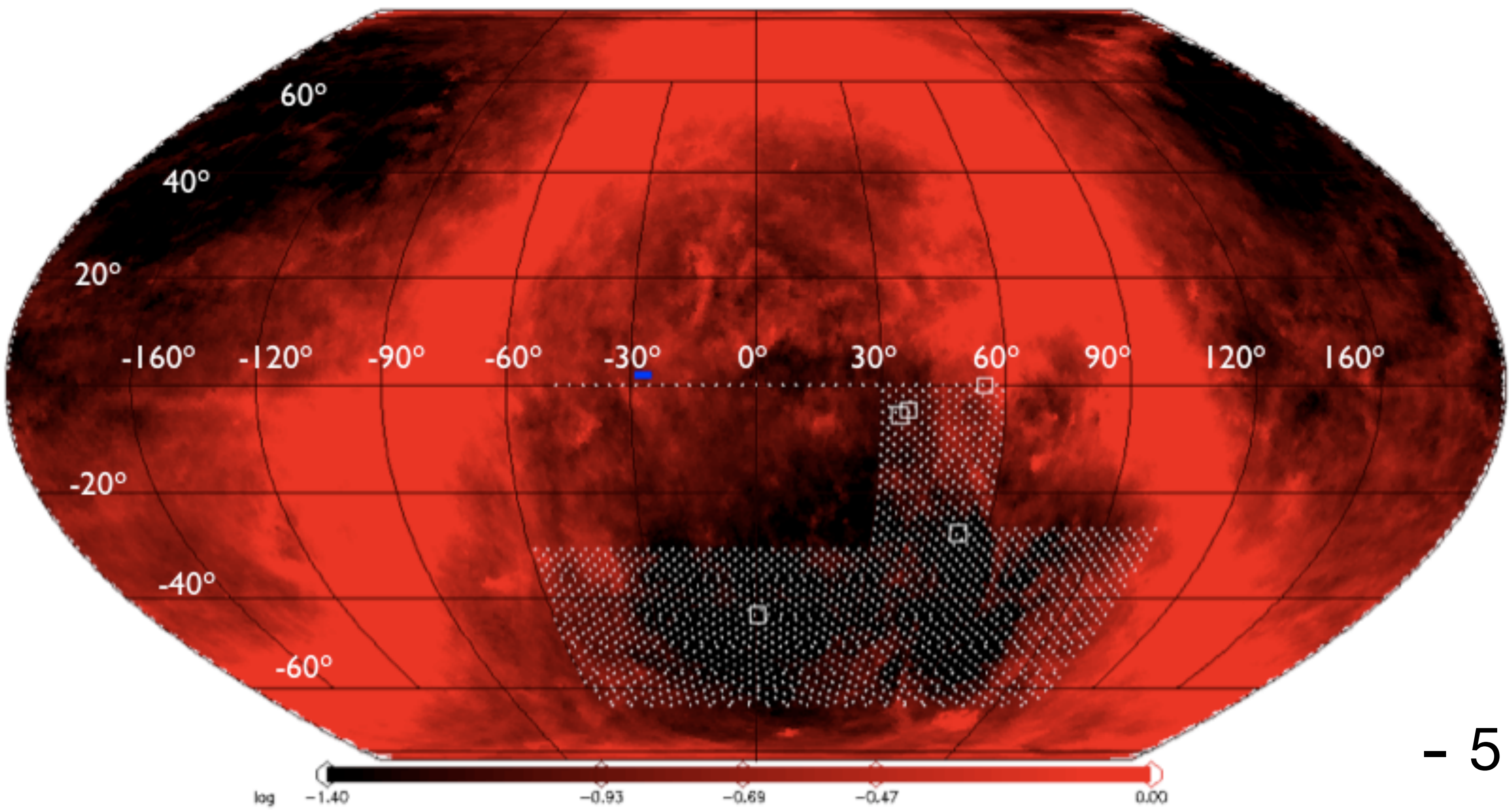
we must add n_eff to this definition.

n_eff uses limiting magnitude and seeing to determine n_eff from a table derived from HST data.

It is of direct use to the WL working group, but it serves to incorporate seeing, sky brightness, and transparency naturally into a definition of completion.

Equivalent tilings is all about area and exposure time. Neff is about delivered data quality.

Survey Strategy I: Strategy



Supernova Fields

	RA	Dec	
CDF South	52.5	-27.5	deep
Stripe 82	55.0	0.0	deep
Elias S1	0.5	-43.5	wide
XMM-LSS	34.5	-5.5	wide
SNLS/VIRM	36.75	-4.5	wide

- 1650 hexes cover the survey area = a tiling
- 2 tilings/year/bandpass
- 1st year has all filters, later years drop filters and increase exposure times
- exposure time in 1st year: 80 seconds

- 5 SN fields
- a SN field visit has
  - z: 10 exposures
  - i: 6 exposures
  - r: 4 exposures
  - g: 2 exposures
- 3 deep fields, 2 shallow fields
  - deep: 300 sec exposures
  - shallow: 100 sec exposures

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Survey Strategy II: Evaluating scenarios

- There exists a survey simulator.
- Was used to perform evaluation of seven scenarios
    1. The new baseline
    2. Delay y-band
    3. Long proper motion baseline
    4. Rethink connection region
    5. Seeing
    6. Maximize survey area
    7. Cover SN fields + 150 sq degrees
- Improvements were needed

    Producing the simulations and doing preliminary evaluation is work to be done.

    1. incorporate sky brightness, especially effect of moon (Krisciunas and Schaefer 1991)
    2. revisit seeing model (Els et al 2009 data)
    3. incorporate n_eff as a metric
        - not completed
- Another round of scenarios, this time with full SC feedback
    1. constant length exposures
    2. finish SPT area first year
    3. Move area east, SPT congruence
    4. others?
- What to give SC: map, mag(filter) for each hex, neff(filter) for each hex

Survey Strategy III: Obstac, mountaintop decision making

- A component of SISPI, written in python. Implements survey strategy
  1. Eric Neilsen@Fermilab
- Conditions determine targets
  1. photometric: perform main survey
     - dark time: g r
     - bright time: i z Y
  2. non-photometric but useable: SN survey
     - transparency > 80%, sky noise < 0.5 mags above normal
  3. opaque: system response curves
  4. time gap trigger on SN: > 7 day gap since last observation of a SN field triggers observation of the field during photometric time
     - 1 SN field per photometric night
     - taken during last half of nightly observing
  5. Limits on observing:
     - < 1.5 airmass for main survey, < 2.0 airmass for SN

Using and testing the new simulator is work to be done, as is re-evaluating program trigger choices.

DES Calibration Simulation I

- We need to understand how the calibration observations drive the survey observations.
- This at heart is the problem of understanding how well global calibrations will do.
- Global calibrations is the act of making use of the massively overlapping images as a calibration tool.
  1. 2nd act star flat: “stack” all observations of multiply observed stars to determine any corrections. This is “2nd” because we will do normal star flats as a matter of course.
  2. More to the point: assume no standards, and see what the multiple observations of stars can do to make a rigid relative calibration

DES Calibration Simulation II

- Simulation tool
  1. Douglas Tuckers Global Calibration Module can be run on the desktop
  2. Douglas also has a tool to generate stars to be fed to GCM
     - this is the heart of the simulation tool.
- What has been done?
  1. The Perfect Instrument model
     - 5000 sq-degrees, two tilings,
     - each DECam image is π sq-degree with no instrumental artifacts
     - stars had reasonable field to field zeropoint variations
     - Result: map had an rms of 0.1 rms
  2. We can add color term related magnitude shifts to stars using DECam predictions
  3. We now have ccd cutouts instead of π sq-degree cutouts
  4. We now have a focal plane and ccd by ccd instrumental offsets

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DES Calibration Simulation III

- What is to be done:
    1. The Rigid Camera Model: given polynomial flat field error, how well does GCM do when solving for a reasonably incorrect model. These are nuisance parameters in the solution, after all
    2. The Perfect CCD Model: given both flat field errors, how well does GCM do? This probably requires revisiting the GCM matrix inversion code
    3. Do this for a reasonable survey strategy model photometric errors
    4. Then, color term induced magnitude shifts as a new error model.
        - write down a likelihood that depends zeropoint, airmass, focal plane flat field, intra-ccd spatial variation, and color term coefficent.

COSMOS- Subaru SuprimeCam

For a single object the real magnitude M_{real} is described by

$$M_{\mathrm{real}} = M + C_r + P_e, \tag{1}$$

where M is the measured magnitude. If we consider a pair of exposures, a and b, we can construct a χ^2 relation as

$$\chi^2 = \sum_{a=0}^{Nexp} \sum_{b=a+1}^{Nexp} \sum_{i=o}^{Nobj} \frac{(M_{i,a} - M_{i,b} + C_{r,a} - C_{r,b} + P_a - P_b)^2}{\sigma_{i,a}^2 + \sigma_{i,b}^2}, \tag{2}$$

which can be minimized to obtain the C_r and P_e factors. Since an object can only belong to one region in each exposure we use the notation $C_{r,a}$ to indicate the region an object belongs to in exposure a.

scattered light corrections

Measured magnitudes

zeropoints

Scattered light correction map

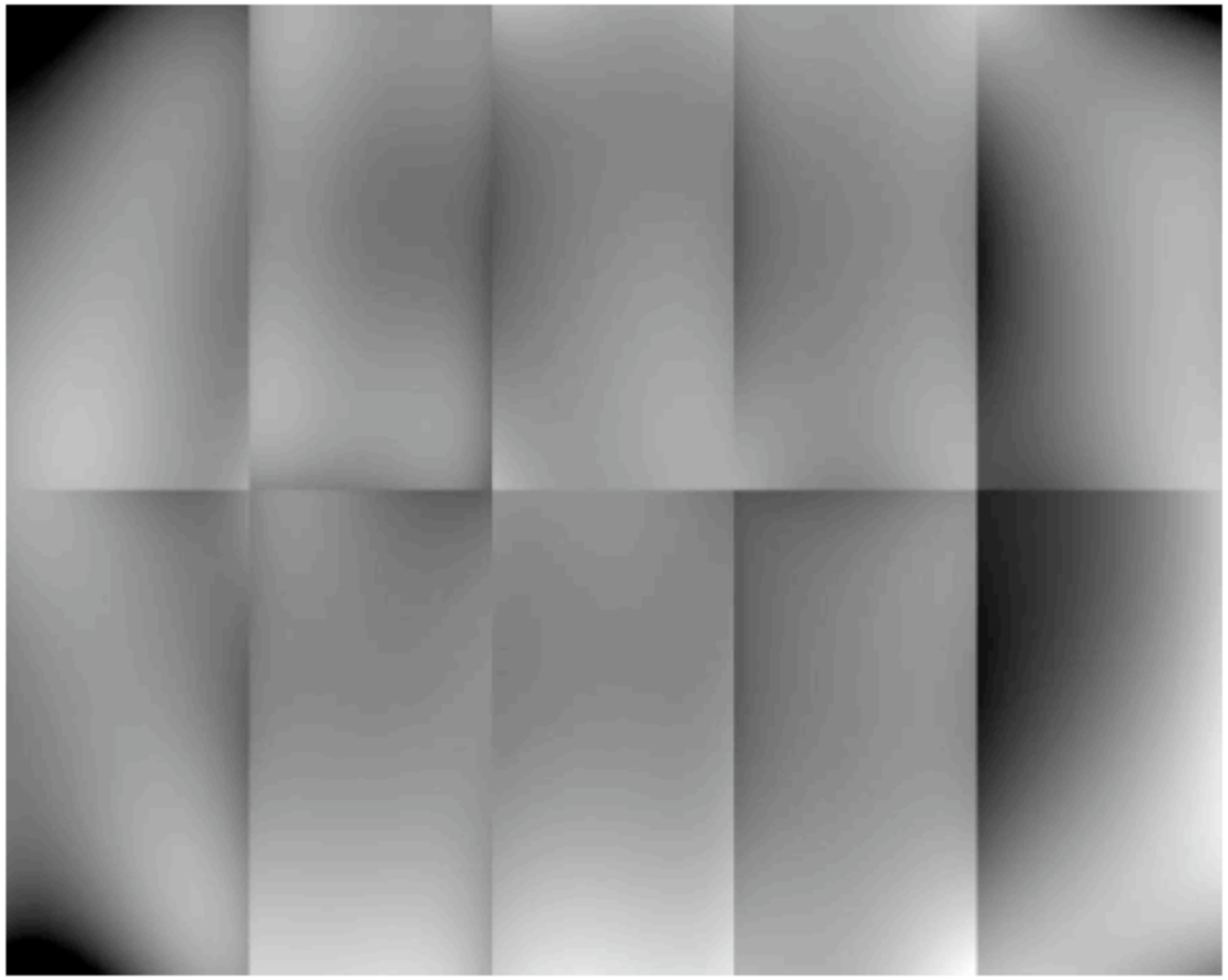

FIG. 6.—Relative correction to the r^+ Suprime-Cam dome flat with chip-to-chip sensitivity variations removed. The scale is linear with a stretch of −3% to +3% from black to white. A correction for scattered light in the vignetted portion of the field is clearly visible around the edge of the field of view.

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SDSS Uber-calibration

3.2. *Solution*

Having specified the parameters of the photometric model, we now turn to the problem of determining them. It is natural to consider repeat observations of stars to constrain these parameters.[19] Let us therefore consider $n_{\rm obs}$ observations with observed instrumental magnitudes $m_{{\rm ADU},j}$, of $n_{\rm star}$ unique stars with unknown true magnitudes m_i. Note that $n_{\rm obs}$ is the number of observations of *all* stars, i.e., $n_{\rm obs} = \sum_{i=1}^{n_{\rm star}} n_i$, where n_i is the number of times star i is observed. Using equation (6), we construct a χ^2 likelihood function for the unknown magnitudes and photometric parameters,

$$\chi^2\left[a_\alpha, k_\beta, (dk/dt)_\beta, f_\gamma\right] = \sum_i^{n_{\rm star}} \chi_i^2, \qquad (7)$$

Measured mags

Instrumental mags

atmosphere

$$\chi_i^2 = \sum_{j \in \mathcal{O}(i)} \left[\frac{m_i - m_{j,{\rm ADU}} - a_{\alpha(j)} + k_{\beta(j)}(t)x - f_{\gamma(j)}}{\sigma_j}\right]^2, \qquad (8)$$

flat field

where j runs over the multiple observations, $\mathcal{O}(i)$, of the ith star, σ is the error in $m_{j,{\rm ADU}}$, and $k(t)$ is given by equation (5). We also assume that errors in observations are independent; this is not strictly true as atmospheric fluctuations temporally correlate different observations. One can generalize the above to take these correlations into account, and, as we show below, our results are not biased by this assumption. Note that equation (7) has $n_{\rm obs}$ known quantities and $n_{star} + n(\text{parameters})$ unknowns. In general, the number of photometric parameters is $\ll n_{\rm star}$, and $n_{\rm obs} > 2n_{\rm star}$, implying that this is an overdetermined system.

Then substituting equation (10) into equation (8) yields a matrix equation for χ^2,

$$\chi^2 = (\boldsymbol{Ap} - \boldsymbol{b})^t \boldsymbol{C}^{-1} (\boldsymbol{Ap} - \boldsymbol{b}), \qquad (12)$$

where $\boldsymbol{A}$ is an $n_{\rm obs} \times n_{\rm par}$ matrix, $\boldsymbol{b}$ is an $n_{\rm obs}$ element vector, and $\boldsymbol{v}^t$ represents the transpose of $\boldsymbol{v}$. The errors are in the covariance matrix $\boldsymbol{C}$, which, in equation (8), is assumed to be diagonal (but can be generalized to include correlations between different observations). For clarity, we explicitly write out the form of $\boldsymbol{Ap} - \boldsymbol{b}$ for the case of a single star observed twice at air mass x_1 and x_2, and with errors σ_1 and σ_2, where only the a- and k-terms are unknown,

$$\left[\begin{pmatrix} 1 & 0 & -x_1 & 0 \\ 0 & 1 & 0 & -x_2 \end{pmatrix} - \begin{pmatrix} I_1 & I_2 & -x_1 I_1 & -x_2 I_2 \\ I_1 & I_2 & -x_1 I_1 & -x_2 I_2 \end{pmatrix}\right] \begin{pmatrix} a_1 \\ a_2 \\ k_1 \\ k_2 \end{pmatrix}$$
$$- \begin{pmatrix} m_{1,{\rm ADU}} - m_{1,{\rm ADU}} I_1 - m_{2,{\rm ADU}} I_2 \\ m_{2,{\rm ADU}} - m_{1,{\rm ADU}} I_1 - m_{2,{\rm ADU}} I_2 \end{pmatrix}, \qquad (13)$$

where I_i is the normalized inverse variance, $I_i = \sigma_i^{-2} / \sum_j \sigma_j^{-2}$. Each row of $\boldsymbol{Ap} - \boldsymbol{b}$ has a simple interpretation as the difference between the magnitude of a particular observation of a star and the inverse variance weighted mean magnitude of all observations of that star. Also, although $\boldsymbol{A}$ is a large matrix ($\sim$50,000,000 $\times$ 2000 for the SDSS), it is extremely sparse and amenable to sparse matrix techniques.

Transition from Commissioning to Survey Mode

- Commissioning is off the 525 night clock, but is limited to ~3 weeks of observing time. Reality is that many of science requirements will not have been verified.
- Priorities in the transition:
  1. Acquire the necessary setup data for the survey
     - e.g., 62-ccd star flat on stripe 82, template images for the SN fields
  2. Acquire data sufficient for testing science requirements
  3. Transition to normal survey observing as quickly as possible
  4. Acquire a small area of full survey depth

- This work takes as starting point (and contributes to) the Commissioning Plan
  1. http://des-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=3734
- and the Science Requirements Document
  1. http://des-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=20

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Overview of other matters

- What is the inventory of useful data on CTIO?
  1. observer provided 30 year weather,
  2. seeing? extinction, sky brightness, moon brightness
- Observing observations and schedule, staffing
- How do we connect CTIO 30 year weather data to sky truth?
  1. can we use standard star observations of Smith and Tucker?
  2. how do we use Precam observations, starting in August?
  3. how do we use infrared cloud camera observations, starting in October?
- Survey mode or bright star avoidance mode?
  1. this perennial red herring* can be stated as
     - what fraction of CCDs have their sky brightness raised by a mag=3 star on the boresight?
     - what fraction of CCDs have their sky brightness raised by a mag=3 star just off the edge of an edge ?

*authors highly biased opinion

Backup slides

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Example scenario evaulation

- The following 4 slides show the type of evaluation done in the last round.
- In those days the simulator handled main survey+SN, now handles calibration stars.

Scenario 1: The New Baseline

- Scenario 1
  - Add y-band in years 1+2
  - Spend year 5 on increasing depth in z by 0.25 mags
    - This fifth year is thought of as contingency- how should we really spend it?
    - only scenarios 3+6 address this

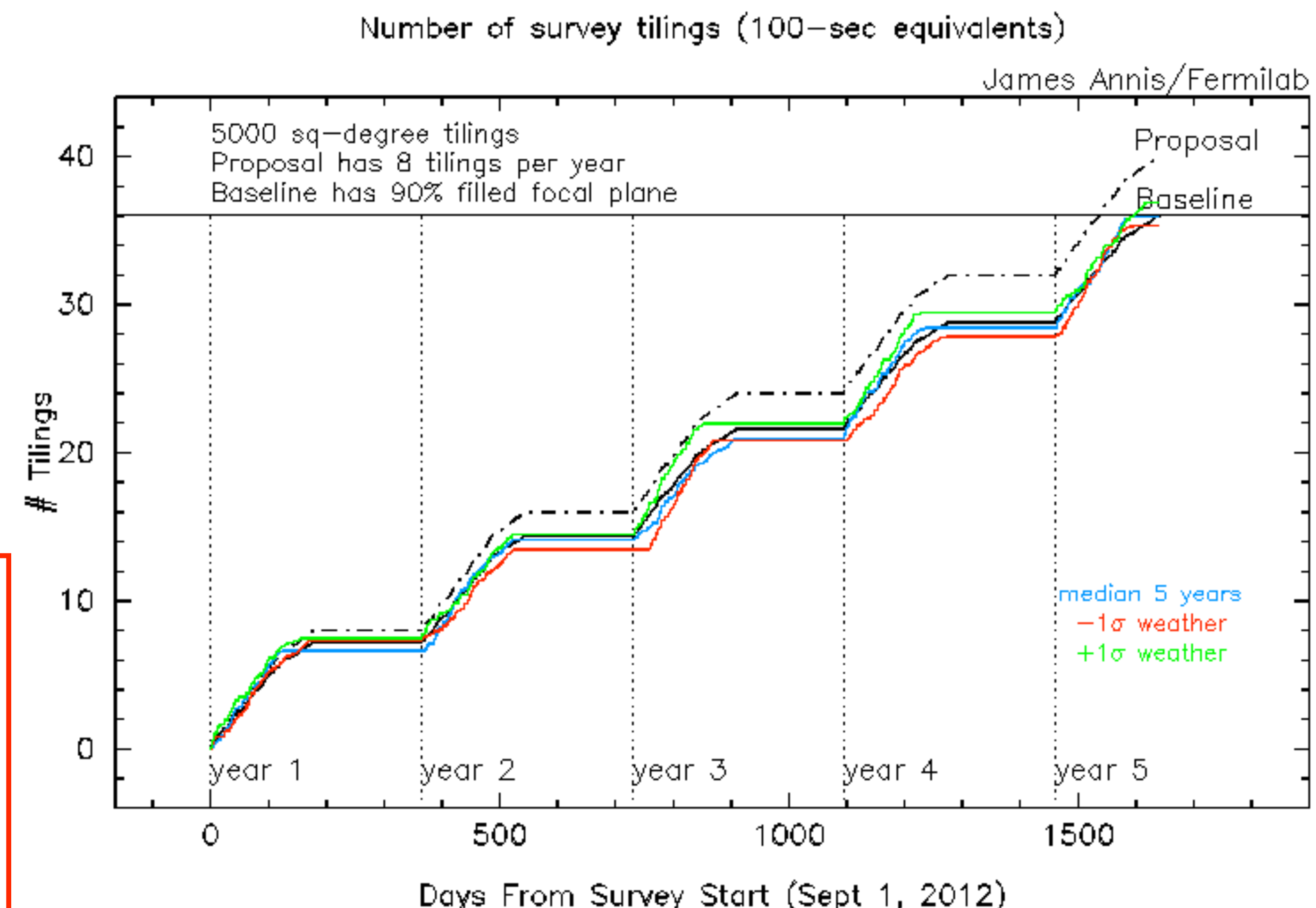
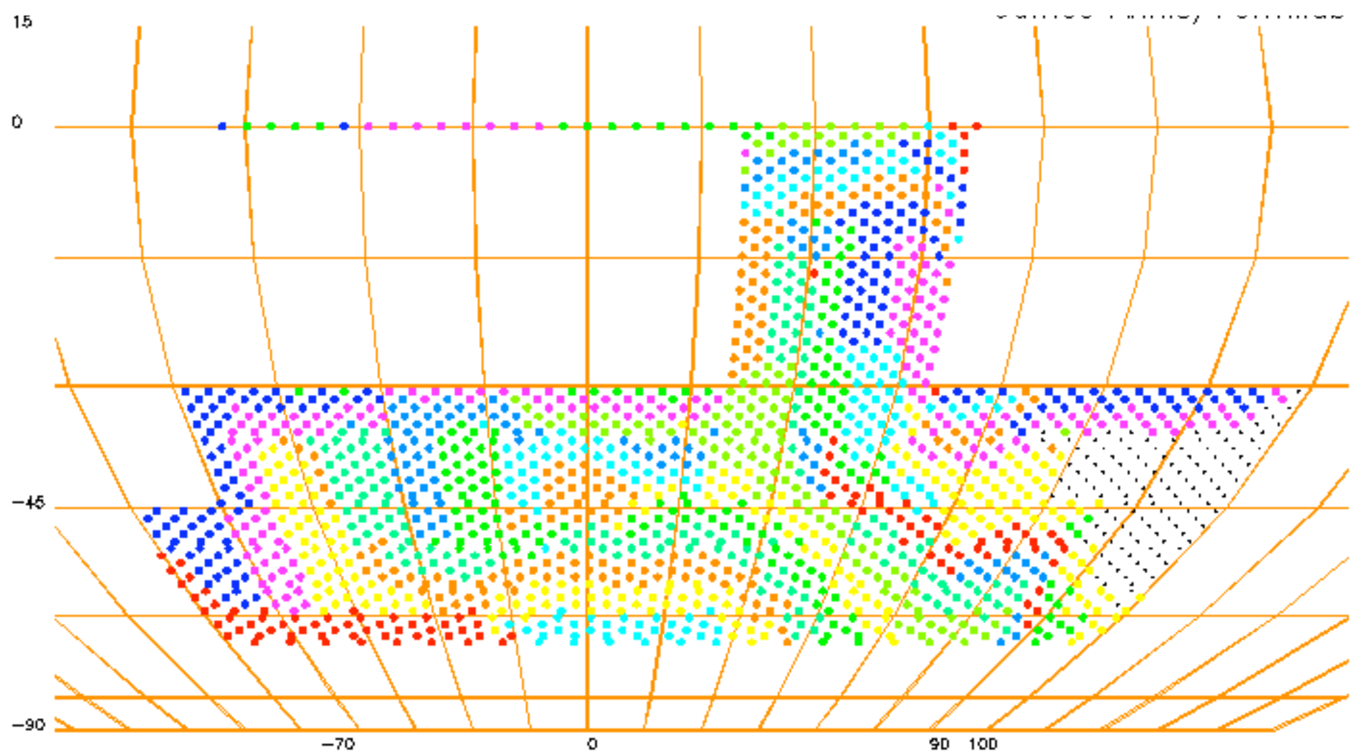


Table 3: Scenario 1 summary

Survey Year	Filters	Exposure time	Tilings	Cumulative exposure g	r	i	z	y	10σ galaxy magnitude g	r	i	z	y
2012	g r i z y	80	2	160	160	160	160	160	24.2	23.7	23.3	22.5	20.9
2013	g r i z y	80	2	320	320	320	320	320	24.6	24.1	23.7	22.9	21.3
2014	i z	200	2			720	720				24.1	23.2	
2015	i z	200	2			1120	1120				24.4	23.6	
2016	z	400	2				1920					23.8	

Scenario 1: The New Baseline



An unusual year- bad weather in Jan/ Feb. Most scenarios show this gap in the East.

Table 5: Quartile distributions

	25%	50%	75%	90%	95%
Slew (degrees)	1.8	2.0	3.1	5.9	23.1
Airmass	1.07	1.16	1.23	1.30	1.34
HA (degrees)	14	35	36	37	38

Observation distributions

75% at airmass < 1.25
75% of slews < 3°
50%-100% at HA ~ 2^{hr} West

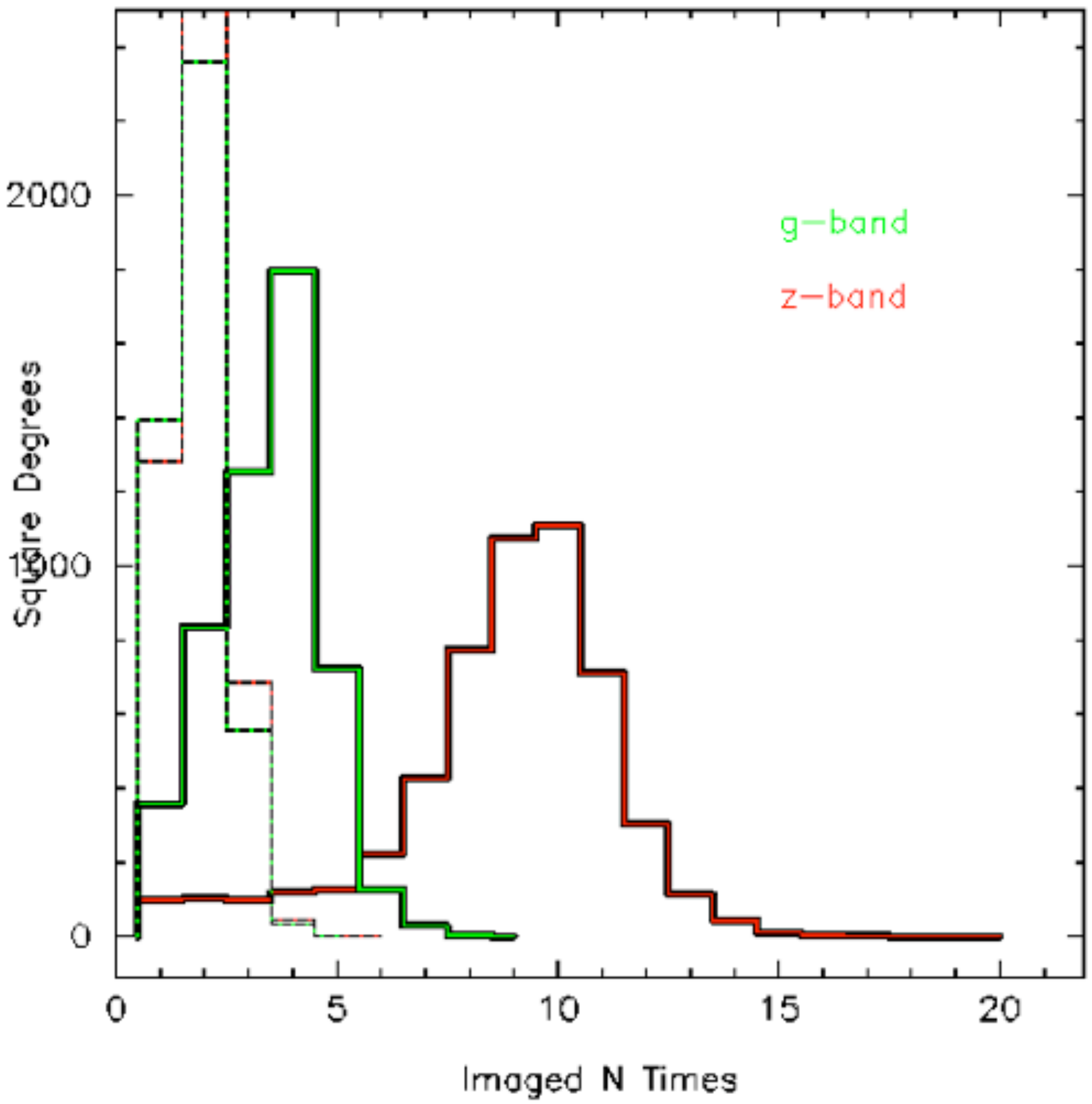
Table 4: Hour use summary for 1989-1993

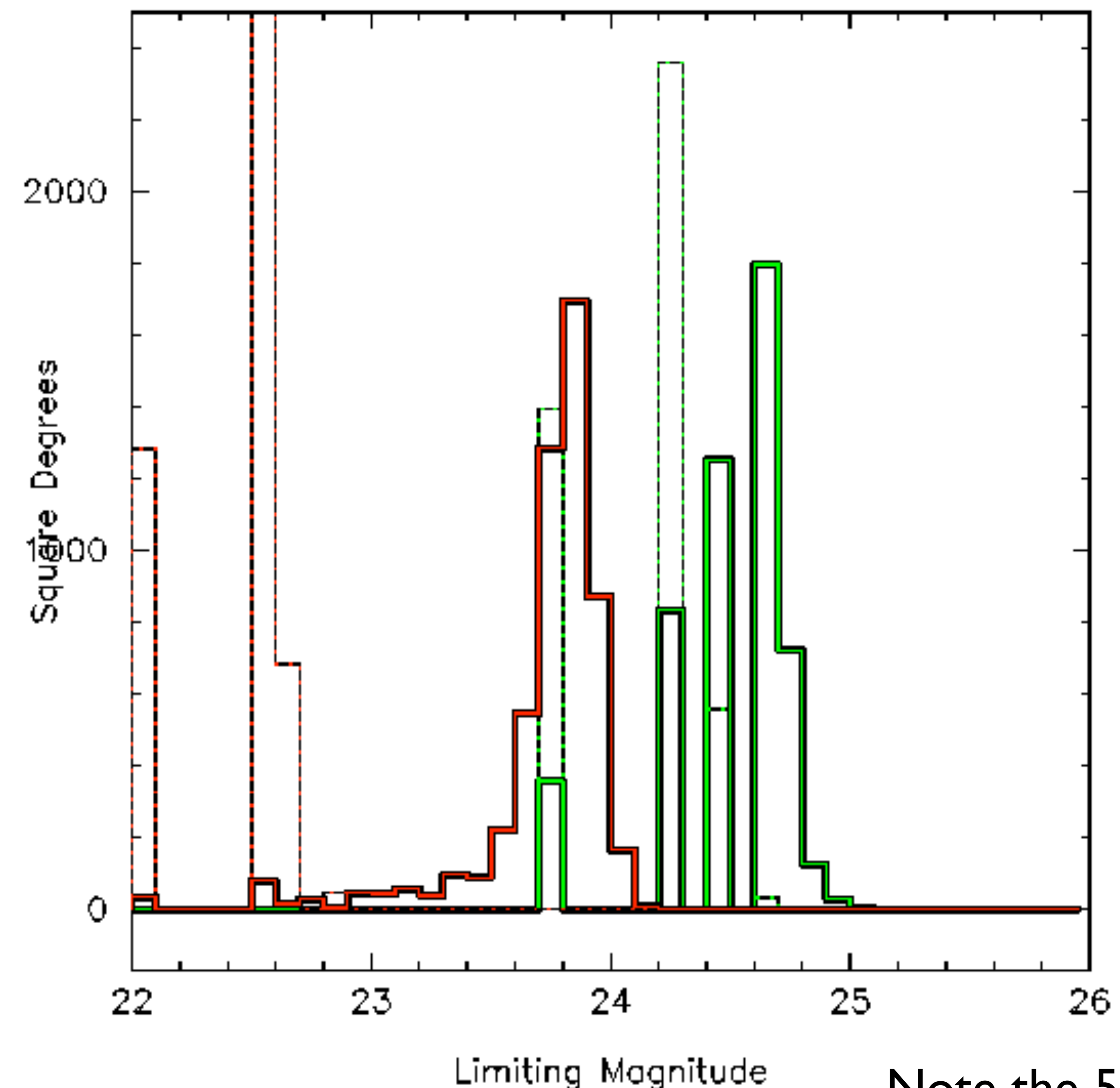
Year	Hrs	On-object	SN photo	SN nonpho	NonPhot	Contingency
1	834	410	37	175	57	0.2%
2	825	464	36	147	53	14%
3	832	371	17	210	90	4%
4	834	405	27	162	52	30%
5	830	387	24	146	54	30%

Contingency is photometric time not spent on observations

Scenario 1: The New Baseline

DARK ENERGY
RVEY





Note the 5-year g-band data comes in discrete magnitudes

- The data are taken in discrete tilings
- The 1st graph shows □° as a function number of visits
- The 2nd graphs show this as function of limiting magnitude
  - red: z-band, green: g-band
  - dotted: year 1, solid: year 5

Scenario 1: The New Baseline

- Supernova Survey
  - five fields
  - allocate all non-photometric time to SN
    - typically 5x > photometric time
  - if time between obs > 7 days, allocate photometric time
    - only one field/night
    - not allowed in first half of night
    - ~8% of photometric time
- Successful, in all scenarios

Table 2: SN Fields

	RA (degrees)	Dec (degrees)	Exposure/visit
CDF South	52.5	-27.5	7300s in 31 images
Stripe 82	55.0	0.0	7300s in 31 images
SNLS/VIRMOS	36.75	-4.5	2430s in 18 images
XMM-LSS	34.5	-5.5	2430s in 18 images
Elais S1	0.5	-43.5	2430s in 18 images